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Views on Emerging Areas of Science and Technology Potentially Important to National Security

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STIC 75-4
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VIEWS ON EMERGING AREAS OF SCIENCE AND TECHNOLOGY POTENTIALLY IMPORTANT TO NATIONAL SECURITY

STIC 75-4

December 1975

SCIENTIFIC AND TECHNICAL INTELLIGENCE COMMITTEE

PREFACE

The prime responsibility of the Scientific and Technical Intelligence Committee (STIC)* is the coordination of Intelligence Community activity in a wide range of sciences and technologies which could affect significantly the military or economic security of the United States.** A recent publication entitled "Intelligence Priorities for the Sciences and Technologies" is a step by the STIC in identifying those sciences and technologies of significance for national intelligence today. Of equal or even greater potential importance is the early recognition of advances in those sciences and technologies which now are emerging but whose full impact on military or economic security may not be felt for some years.

Their recognition early enough would provide ample time to collect and analyze data on foreign activities in those areas while they are still relatively easy to obtain. Accurate specification of these areas will enable the Intelligence Community to concentrate its efforts better and possibly avoid a foreign S&T surprise in the future.

An essential first step to narrow the possibilities is to obtain the views of a number of qualified individuals. This first step has been undertaken as an ongoing STIC project and this report is the product of Phase I. It is not an intelligence assessment but is a selection of some of the viewpoints expressed by a number of such persons as of a particular time—early and mid-1975. Its purpose is to stimulate the Intelligence Community into early planning for future collection and analysis of new and unusual intelligence targets.

The material presented in this report is based on information received from individual interviews with some 17 persons. All have recognized achievements in science or engineering; most have had extensive associations with military technology problems. They included two Nobel prizewinners, several laboratory directors, former high-level government technical personnel, and Department of Defense and Intelligence Community contractors. The group was roughly balanced between scientists and engineers. The results are presented as identified areas of science and technology as well as emerging problem areas expected to be of importance in the future.

Although the number of individuals interviewed is not large, the sampling is considered to be good in the areas of science and military

*Formerly the Scientific Intelligence Committee (SIC).

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security. Respondents representing areas of science and technology related to the future economic welfare and energy developments were not significantly represented. Phase II of this project, by increasing the sample size and by broadening the spectrum of respondents, skills, and expertise, will minimize any biases. At the end of the project, a final definitive report will be prepared with specific recommendations. This project has been sponsored by the STIC and any comments regarding it would be welcomed. Please call the STIC Secretariat, 6F35, CIA Headquarters [redacted] 25X1

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INTRODUCTION

Following the surge of science and technology in World War II and about every 10 years since, concerted attempts have been made to divine what S&T areas had reached or were about to reach the "take-off point" for future development or exploitation in military technology.* Each of these efforts involved input from a large number of persons who were knowledgeable in a broad spectrum of sciences and technologies. Our effort has been much more modest and, even including succeeding phases, will involve a much smaller group, perhaps 30-40 persons. We believe that useful forecasts can be made by a smaller group if the participants are carefully selected and properly approached.

We selected recognized authorities who are in touch with more than a single specialized field and who know where the "ferment" is in a number of disciplines. At the same time, we chose individuals who are in contact with the talented bench-level scientist and thus can argue for exotic ideas which may not yet be technically or organizationally acceptable. Our interview approach was interpersonal. We felt that simply asking a scientist or engineer to answer a written question would not give us the kind of response desired. Instead we met with them on essentially a one-to-one basis, although each may have had different areas of interest. We felt that an immediate conversational feedback would produce a more significant interchange and stimulate a wider spectrum of ideas. The STIC asked Dr. Stephen J. Lukasik, former Director of the Defense Advanced Research Projects Agency, to take part in this project. He in fact conducted many of the interviews, accompanied by a representative of the STIC, and performed the basic analysis of the interview data.

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In planning and carrying out this project, we recognized sources of bias in our methodology that could distort the results and made conscious efforts to minimize them, recognizing that they were not entirely avoidable. First, was that the persons selected for interviews would in essence determine the answers to our question. Thus, particular care was exercised in selecting a knowledgeable sample representing as wide a spectrum as possible within the constraint of the small sample size. Second, in the initial portion of each interview, we encouraged extensive free exposition on the part of our respondents before interacting with them in order to avoid leading them. Third, among the sometimes numerous topics brought up in each interview, it became a subjective decision as to what to note, whether a main point or a digression, which in itself could be significant.

Those interviewed had wide backgrounds and they were encouraged to range broadly. Thus they were not confined to specific fields of expertise. Further it should be noted that there are varying degrees of probability to be attached to their views and also, that the time frame in which these expectations might be realized is highly uncertain, variable, and clearly extends beyond the period of the 80's in some cases.

In the analysis of the interview data, what to consider most or least important again involved a subjective judgment. While this judgment may be questioned, we feel that the results reported here express the main thrusts of the responses. The interviews were based on one key question:

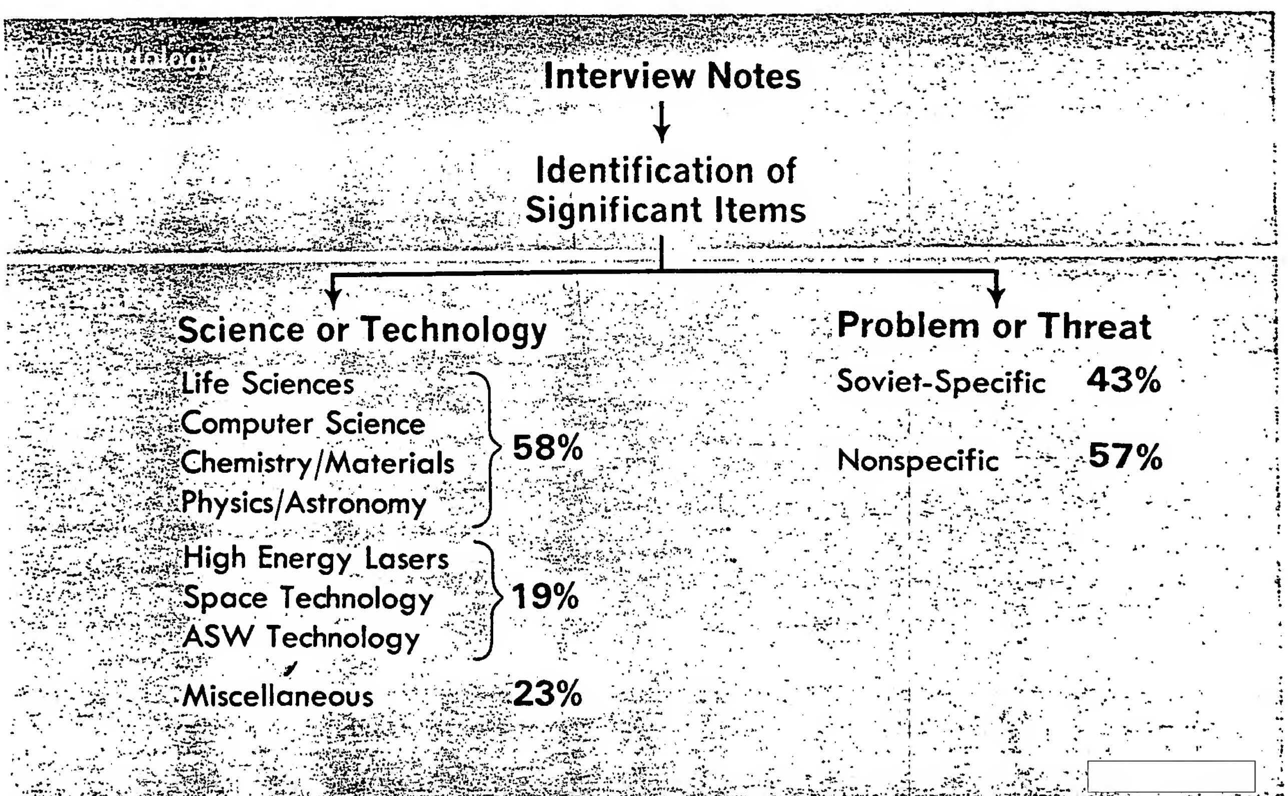
> **"What are the emerging or rapidly moving areas of science or technology potentially important to national security in the 80's?"**

SUMMARY

The significant topics from the interviews were found to divide in a roughly 2:1 ratio into two classes: those concerning an area of science or technology and those concerning a problem or threat area. (See chart below.) Each class was ordered internally to discern whatever patterns of ideas might be present. In some cases the same idea was mentioned by more than one person while in others several ideas clustered in certain areas or around certain themes. Each of these clusters could then be weighted in importance according to both the number of items in it and the number of individuals contributing to it.

Of the science and technology items, nearly three fifths fell into four clusters: life sciences, computer science, chemistry/materials, and physics/astronomy. The next three clusters, in order of frequency of mention, covered the technology areas of high energy lasers, space, and antisubmarine warfare and accounted for slightly less than a fifth of the items. The remainder, slightly more than a fifth, consisted of a set of ideas mentioned only once and which did not fall into any of the popular clusters.

The problems or threats divided almost equally into two classes, those requiring resources of such a magnitude that only the Soviet Union could reasonably be considered to pose such threats and those requiring a lesser level of resources such that other countries or groups could also credibly pose such threats. Within each of these, the significant clustering was into threats of a military



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nature and those of an economic character. In the following discussion section, the ideas in each of the major clusters are detailed.

The results of the Phase I effort are summarized in the following two charts. The topics thereon are particularly noteworthy both because of the likelihood of their realization and of their potential significance should scientific expectations be realized. There are some areas which received little emphasis although they also might pose threats over the long range. Among these were conventional land warfare, electronic warfare, and computer vulnerability. These as well as others, may emerge in the next phase of the study.

WHAT STANDS OUT IN SCIENCE § TECHNOLOGY?

- Genetic engineering
- Understanding the brain and the nature of thought
- Possibility of interaction with intelligent extraterrestrial life
- Logic devices that will be cheap, smart, human-adaptive, and widely distributed
- The synthesis of complex organic materials tailored for specific biological or physical properties
- Understanding subnuclear interactions and the possibility of new energy and radiation sources
- High energy laser in space
- Construction of large structures in space
- Major advance in ASW that could seriously impact our undersea deterrent

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WHAT PROBLEMS/THREATS ARE FORESEEN?

- Nonspecific general threats are seen to outweigh Soviet-specific high technology threats
- Nonspecific general threats are highly economics-related while Soviet-specific threats are not seen as primarily economic in nature
- Some unusual threats that stand out are:
  - Soviet attacks on or from space
  - Economic warfare
  - Agricultural/chemical warfare
  - Weather/climate modification
- Laser isotope separation is expected to result in increased nuclear proliferation
- Break-up of US alliances is seen to put a premium on naval superiority but at the same time one wants to look for unconventional means of global transport

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DISCUSSION

EXPECTATIONS IN THE LIFE SCIENCES

The single area of science mentioned most often was that of the life sciences, accounting for almost a quarter of the significant items. One respondent said as his opening remark that "The scientific surprises will be in biology. It is the terra incognita." Another referred to cellular biochemistry as a "maximum intellectual opportunity." Several felt that over the time period in question we will begin to understand the working of the human brain, both at the neurophysiological level and at the cognitive level. The belief was expressed that at the physiological level we will understand cellular receptor mechanisms and the input/output processes of the brain. It was felt that such fundamental understanding would then translate into a better understanding of such cognitive processes as judgment, intuition, creativity, learning, and problem solving.

There were several references to the effects of microwave radiation on humans and the possibility of inducing behavioral changes by the manipulation of electrical rhythms in the brain. Sleep, alertness, learning, optimizing task performance, and mood-altering were mentioned as possible applications. In a similar vein, the possible use of the Josephson junction to obtain an electro- or magneto-encephalogram remotely was mentioned as a means of monitoring individual behavior or mood.

Another area mentioned as a likely development is that of genetic engineering. Recent research on recombinant DNA molecules suggests the threshold of a new area of scientific and engineering opportunity. Despite current ethical discussions among the broad community of scientists involved, the feeling was expressed by several respondents that we would be both forced into such a development by the need to enlarge the world food supply as well as drawn into it by enormous commercial incentives. The applications will all be at the bacterial level and will occur first in industrial sectors dealing with antibiotics, fermentation, and allied chemical processing. Direct fixation of nitrogen for fertilizer, the production of hydrogen for energy, and the synthetic production of human protein for therapeutic purposes are some of the possible incentives.

In each of these areas, there are clearly both benefits as well as risks and these were recognized and discussed by the interviewees. But the consensus was that a combination of the scientific imperative, social needs, and economic incentives would result in the ultimate realization of these potentialities.

Several of the group chose to discuss living matter from the viewpoint that amino acids are not unique to the terrestrial environment, that life elsewhere is inevitable and widespread, that intelligent life is common, that there is a considerable similarity between these life forms, and that contact between them occurs. Some thought that the potential exists for some form of faster-than-light communications or travel although no one suggested that man is likely to achieve it in the near future. Possibly related to this, a feeling was expressed that there may be some genuine anomalies in the mass of UFO experiences.

Another hint of a new direction in science that was mentioned lies in the area of parapsychology. Here again, the opinion was expressed that there is a possibility of such phenomena as precognition and psychic communication in spite of the mass of poor science, pseudoscience, and outright fraud that surrounds the field. The view of some is that at least some forms of psychic phenomena may be explained on the basis of an unusual sensitivity of certain individuals to certain low-level signals whose origin is actually explainable by current science.

EXPECTATIONS IN THE PHYSICAL SCIENCES

Cheap computation was taken as a fundamental determinant of the scientific and technological future. In such a circumstance the efficiency with which hardware is employed becomes less important; also it is reasonable that more special-purpose computers will be constructed, often on one or a

few large-scale-integration circuit chips. The cost and reliability of software then become the driving forces. In particular it is important to understand the logic implications of complex software, including conditions of hardware failure or malicious penetration of the hardware-sofeware system.

Although some of the discussions focused on technological issues such as unusual architectures that will be enabled with the advent of cheap large-scale-integration circuit chips (e.g., 10^4 parallel processors), the impact of charge coupled devices, and cheap high-density random access memory (say 10^{11} bits), the bulk of the comments centered on the impact of such hardware capability. The dominant theme was that these advances would have a major impact on the speed and efficiency with which people will communicate with each other and with logic systems. For as more machine capability per unit cost becomes available, the systems themselves will be able to respond in more human-like ways. Adjectives such as "smart" and "friendly" were used repeatedly to describe future computer systems. The new methods of response will greatly broaden their range of applications—uses for purely numerical computations will lessen, while more cognitive areas such as problem solving, hypothesis testing, economic planning and social systems management will increase.

These logic and computational capabilities will have a fundamental impact not only on weapon system performance but also on military security directly. For computer science will directly translate into command, control, and communication capability, and this per se can enhance the effectiveness of a military force.

In chemistry, several fields were identified as being of particular interest. The borderline area between inorganic and organic chemistry was identified for both the richness of possible compounds with unusual physical and chemical properties (stereospecific, photovoltaic, anisotropic, etc.) as well as for its relatively unexplored character. The role of such compounds in catalyzing the fixation of nitrogen was mentioned for its application to the production of critically short fertilizers.

Organic synthesis was mentioned as an area of potential impact, especially the synthesis of biochemicals such as insect hormones and specific insecticides. In a rather different aspect of organic synthesis, work is under way to produce organic molecules capable of sustaining super-conductivity at relatively high temperatures—possibly even at room temperatures. This requires a much deeper understanding of the relationship between molecular structure and the phenomena responsible for its bulk electrical properties.

Catalysis and surface chemistry will be areas of particular activity driven both by the need for ever more efficent industrial production as well as our increasing reliance on thin film devices in electronics. Considerable theoretical discussion has centered on a possible metallic form of hydrogen at extremely high pressure. What precisely will come from the production of metallic hydrogen is difficult to predict, but it is certain to provide a substantial degree of scientific stimulation. The same is the case with a gamma ray laser. It could provide us with a totally new tool which might enable us to manipulate matter selectively at the level of the individual lattice site.

In physics, the projections focus on completing the solution of one of the major outstanding problems, that of understanding the nature of the strong interactions. The current bewildering variety of hypotheses is expected to be replaced by an orderly description. Such an understanding is certain to generate applications as particles become susceptible to prediction and manipulation. Perhaps we will discover a way to achieve complete mass/energy conversion (9MT/lb); at least there will be new ways of economically producing energy, radiation, and new materials. In the same vein, the hypothesized tachyon that travels at a speed greater than light attests to the vigor and eventual revolutionary impact of high energy particle physics.

In a different direction, but possibly just as revolutionary, is the current ferment in astronomy and astrophysics. Quasars, neutron stars, and black holes represent totally new systems to be understood. In at least some of these systems, the mass and energy densities may be so great that fundamental revisions of the laws of physics may be necessary to describe them, revisions which have imperceptible consequences under the circumstances of "ordinary matter." Thus it will be useful

to follow work in these areas since it may be here that the fundamentally new thoughts may emerge. How these will be applied is difficult to say but one can expect at the least to discover new ways to exploit energy.

Finally, one can expect some day to achieve the long-sought unified field theory that will unite under a common description the diverse physics of electromagnetism, gravitation, strong interactions, and weak interactions. When one does, one might expect to understand how to control gravitational forces for propulsion and energy production.

EXPECTATIONS IN TECHNOLOGY

Lasers were the single most-often-mentioned technology having a potentially revolutionary impact. The high energy laser as a weapon was mentioned several times although in one respondent's opinion its potential as a weapon is overrated. The high energy laser in space was felt to be particularly likely and significant as a threat either to satellites or to high-altitude aircraft. Other applications mentioned included a ground-based laser radar for ABM discrimination or precise space object identification. The only device-specific opinion was on the importance of the chemical laser, not only for its power-production capability, but also for its ability to control specific states of chemical excitation in order to optimize production processes.

Space technology was also discussed in the context of new applications made possible by large structures in space. The high energy laser in space has already been mentioned as a totally new military capability, especially for attacks on other spacecraft. A radar in space, either at synchronous or lower altitude, offers significant opportunities for tracking aircraft and surface ships. The possibility of fabricating in situ enormously large antennas in space, using uniquely zero-g techniques, was noted. Large solar arrays in space, transmitting their energy to earth or other orbiting objects via narrow microwave beams were mentioned as energy sources. The construction of space stations was considered a development that would be enabled by the space shuttle. Finally, the continued development of satellites for an increasing range of communication functions was envisaged. Running through the entire discussion was the projection that the next step in space technology will be the construction and use of very large spacecraft where the size is a necessary feature for achieving the desired capability.

An explicit military technology that was mentioned was that related to antisubmarine warfare. The general feeling among several of the respondents was that the continued invulnerability of the strategic undersea deterrent could be seriously questioned. Several felt that acoustic sensor and signal processing technologies are likely to experience a major improvement, while another felt that nonacoustic techniques are more likely to provide the significant change in the state-of-the-art. But, regardless of the precise direction in which changes might occur, the feeling is that the ASW area is ripe for major technological advance.

TOPICS RECEIVING SINGLE MENTIONS

Fluid dynamics was mentioned as an area possibly due for a major change, in both the understanding of turbulence and also the control of the laminar-turbulent transition as well as our computational capability to handle the optimization of three-dimensional flows numerically.

Covert underwater remotely piloted vehicles were discussed by one individual, while another pointed out that advances occurring in inertial guidance technology were likely to have a major impact on our ability to navigate under water.

Radar technology was seen as moving into the higher frequency (50-100 GHz), wider bandwidth region both for high resolution active-mode applications as well as for passive-mode seekers.

The need for long endurance aircraft was projected; both small remotely piloted solar-powered vehicles for surveillance and relay purposes and dirigibles as a logistics alternative to surface ships were mentioned.

Aircraft signatures, both IR and radar, were seen as a cause for concern, the former from the standpoint of the likelihood of passive target acquisition and the latter as a speculation into what kinds of tactical aircraft were likely to result should minimization of the radar cross section drive the design.

Hypersonic aircraft driven by supersonic combustion ramjets and capable of achieving orbital velocities were seen as a possibility by one respondent.

Another saw charged particle beam weapons as a possibility.

SOVIET-SPECIFIC THREATS

As might be expected, a number of concerns were voiced about Soviet activities and threats. The Soviet capability to wage war in and from space, the likelihood of such a development, and a possibly greater future dependence of the US than the Soviets on space systems was remarked by several people. The vigor of the Soviet R&D program in high energy lasers, ABM technology, cruise missiles, and very high yield nuclear weapons was emphasized and the possibility of surprises to the US by virtue of our conceivably lesser understanding was expressed. This same concern was directed even more strongly to the case of the life sciences in general and genetic engineering in particular. The feeling of several respondents was that the Soviet Union may investigate what we will choose not to, with consequent possible crisis implications in the future.

On a more politico-military theme, a shift in the military balance to the Soviets was expressed, especially in areas such as the Mediterranean where naval superiority is crucial. The break-up of traditional US alliances was also noted and, hence, the need for the US to project its power without the land bases and ocean control we have enjoyed in the past was emphasized. Finally, it was felt that the success the Soviets have had in aligning with insurgents could be a factor in future shifts in the global balance. At the same time, the potential role of technology in compensating for these political developments was pointed out, especially in new ways to provide global transportation that is less dependent on overseas bases.

While the discussion of Soviet-specific threats followed a fairly conventional military line, there was some speculation of a more economic/managerial type. One respondent emphasized the effect of the Soviet social organization on inhibiting progress and, hence, the potential for a rapidly growing economic capability if those inhibitions could be overcome. This led to a discussion of technology transfer and the ways in which the Soviet system could change dramatically as the result of wider economic, technological, and cultural contacts. Another interviewee expressed concern that the Soviets may have an effective crop forecasting system that does or could give them an important market advantage.

NONSPECIFIC THREATS

Slightly over half of the threats to national security that were voiced were of such a nature that they could not be directly or uniquely identified with the Soviet Union alone. For the most part, the threats could be characterized as unconventional attacks, often economic in their nature or impact, and involving low levels of violence.

One major theme consists of observations concerning the projected worldwide scarcity of resources; shortages of or artificial constraints on materials critical to national security; over-population and famine projections; and agricultural/chemical warfare directed against food supplies. The essence of these arguments is that the world will suffer from these shortages, leading directly to tension and violence or their manipulation in a form of economic warfare.

Closely coupled to this is the possibility of weather and/or climate control. While the techniques and objectives of these two activities would be somewhat different, they differ scientifically only in the temporal and spatial scale over which control is exercised and, hence, will be considered together. Climatological warfare could be initiated as a hostile act or it could result from well-intentioned attempts at national development, particularly development aimed at increasing the supply of food. This, in turn, could be motivated by internal needs or by a desire to acquire security-bargaining chips.

Thus, a substantial case is made that some of the fundamental metrics of national security may arise not out of classical force ratios but instead will be derived from indicators of economic activity. This led one interviewee to speculate about how we could even tell if economic warfare is being waged and how we would chart its progress. An-

other argued that such economic activity organized in support of national goals and policies is a natural mode of behavior for a planned, socialist state. Finally, the differences between purely national and multinational business entities were noted from the standpoint of the inherent difficulty in identifying the "combatants."

A second major theme involves somewhat greater levels of violence and relates to terrorist activities and n^{th} country nuclear threats. The possibility that terrorists might steal or build weapons was mentioned, as was the inexpensive and relatively low level of technology requisite for certain kinds of chemical and biological warfare, whether practiced by terrorists or n^{th} countries.

Nuclear proliferation was foreseen as a future threat, especially as it will be encouraged and facilitated by the development of laser isotope separation. Access to ^{235}U can be expected to be relatively easy, for subnational groups as well as nation-states, quite independently of the growth of nuclear power facilities. And with the widespread availability of fissionable materials will come the increased likelihood of terrorist nuclear threats.

Competition for the seabed was mentioned, although the context was antisubmarine warfare and other strategic military issues instead of the food and material resources foci that one might have expected.

The ease of penetration of computer-based command and control systems was mentioned, while another respondent raised questions about the stability of our present physical security arrangements with respect to theft, sabotage, the actions of the psychotic personality, and accidental war. Another raised the likelihood of unidentified attacks—that is, the inherent difficulty of identifying the authentic source of the threat, and thus, the precipitation of hostilities through third-party provocation or inadvertence.

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